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ABSTRACT

This unit of instruction covers the theory of ultrasonic sound, methods of applying soundwaves to test specimens and interpreting results, calibrating the ultrasonic equipment, and the use of standards. Study periods, group discussions, and extensive use of textbooks and training manuals are to be used. These are listed along with references and periodicals. Goals, specific block objectives, and a bibliography are included in the booklet. A quinmester posttest sample is included. (EB)

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# AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

DADE COUNTY PUBLIC SCHOOLS

Course Outline
AVIATION QUALITY CONTROL - ADVANCED - 9227
(Ultrasonic Testing)
Department 48 - Quin 9227.03

DIVISION OF INSTRUCTION • 1973

ED 093610

D A D E  C O U N T Y  P U B L I C  S C H O O L S

1450 NORTHEAST SECOND AVENUE

M I A M I,  F L O R I D A  33132

Course Outline

# AVIATION QUALITY CONTROL - ADVANCED - 9227
(Ultrasonic Testing)

Department 48 - Quin 9227.03

county office of

VOCATIONAL AND ADULT EDUCATION

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Dr. E. L. Whigham, Superintendent of Schools
Dade County Public Schools
Miami, Florida 33132

November, 1972

Published by the School Board of Dade County

## Course Description

| 9227 | 48 | 9227.03 | Ultrasonic Testing |
|---|---|---|---|
| State Category Number | County Dept. Number | County Course Number | Course Title |

This course covers the theory of ultrasonic sound; methods of applying soundwaves to test specimens and interpreting results; calibrating the ultrasonic equipment; and the use of standards.

Clock Hours: 135

# PREFACE

The following quinmester course outline will serve as a guide for the high school or adult trainee in testing, inspecting and checking parts and materials to insure the quality and reliability of the finished product.

This outline consists of eight blocks of instruction which are subdivided into several units each. These blocks will involve the techniques of applying ultrasonic waves for materials and parts testing. Calibration of the equipment, use of standards, safety and work precautions will be dealth with. The necessary applied theory of sound will also be covered. This course is 135 hours in length.

Adequate laboratory time and actual experience on aircraft and other equipment will be provided to develop skills in the student.

The student will work with and receive substantial drill in the use of actual equipment used in the NDT field. Motion picture films and color slides will be used to bring into the classroom the application of these techniques.

Study periods, group discussions, and extensive use of textbooks and training manuals will be used. These are listed along with references and periodicals.

This outline was developed through the cooperative efforts of the instructional and supervisory personnel, the Quinmester Advisory Committee, and the Vocational Curriculum Materials Service, and has been approved by the Dade County Vocational Curriculum Committee.

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BLOCK

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|---|---|---|
| I. | THEORY OF SOUND (25 Hours) | |
| | Methods of Sound Wave Generation | 1 |
| | Wave Forms of Ultrasonic Sound | 1 |
| | Ultrasonic Sound Wave Propagation | 1 |
| | Ultrasonic Sound Wave Frequency | 1 |
| | Ultrasonic Sound Wavelength | 1 |
| | Ultrasonic Sound Wave Velocity | 1 |
| | Reflection and Refraction of Ultrasonic Sound Waves | 1 |
| | Sound Beam Spread or Divergence | 2 |
| | Sound Beam Attenuation | 2 |
| | Sound Beam Impedance | 2 |
| II. | EQUIPMENT USED IN ULTRASONIC TESTING (10 Hours) | |
| | The Ultrasonic Reflectoscope | 2 |
| | The Transigate | 2 |
| | Immersion Tank | 2 |
| | Search Units (Transducers) | 2 |
| III. | TECHNIQUES IN USING ULTRASONIC EQUIPMENT (50 Hours) | |
| | Proper Selection of Search Units | 3 |
| | Search Unit Couplant | 3 |
| | Pulse Echo Technique | 3 |
| | Through Transmission Technique | 3 |
| | Immersion Technique | 3 |
| | Angle Beam Technique | 3 |
| | Setting Up the Reflectoscope | 3 |
| IV. | INTERPRETATION OF INDICATIONS (10 Hours) | |
| | Cathode Ray Tube Display (A-Scan) | 3 |
| | Facsimile Recorder (C-Scan) | 4 |
| V. | USE OF STANDARD REFERENCE BLOCKS (30 Hours) | |
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| | Area Amplitude Calibration Blocks | 4 |
| | Distance Amplitude Calibration Blocks | 4 |
| VI. | ADVANTAGES AND LIMITATIONS OF ULTRASONIC TESTING (5 Hours) | |
| | Depth Penetration of Sound Waves | 4 |
| | Near Surface Resolution | 4 |
| | Portability of Equipment | 4 |
| | Ability To Work from One Surface | 4 |
| | Type of Presentation | 4 |

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VII. SAFETY AND WORK PRECAUTIONS (5 Hours)
Danger, If Any, To Operating Personnel . . . . . 4
Complexity of Instruments and Delicate Crystals . . . . 4

VIII. QUINMESTER POST-TEST

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## GOALS

The student must be able to:

1. Develop skills in the use of ultrasonic test equipment, its application and correct interpretation of indications.

2. Develop the attitudes of patience and persistence to gain maximum accuracy.

3. Develop the habits of cleanliness of person and work area.

4. Be aware of the responsibility involved in his chosen work.

5. Maintain the standards required for the field.

6. Control quality of the finished product.

## SPECIFIC BLOCK OBJECTIVES

### BLOCK I - THEORY OF SOUND

The student must be able to:

1. Discuss the piezoelectric and magnetostrictive principles of sound wave generation.
2. Show by diagramming on paper three sound wave modes and their particle movement.
3. Explain the terms frequency and wavelength.
4. Solve a problem on wavelength, given frequency and velocity.
5. Work at least three variations of Snell's Law involving refraction and the first and second critical angles.
6. Calculate beam spread half angle given wavelength and crystal diameter. Work at least two problems.
7. Explain acoustic impedance and express the formula in writing.

### BLOCK II - EQUIPMENT USED IN ULTRASONIC TESTING

The student must be able to:

1. Reset the cathode ray tube display screwdriver adjustments, after the display has been brought out of adjustment.
2. Set up a display including the marker sweep, on the cathode ray tube using the test block and the large hole.
3. Set up a display, on the cathode ray tube, using the transigate on the large hole in the test block.
4. List the materials used for crystals in making the search units.

### BLOCK III - TECHNIQUES IN USING ULTRASONIC EQUIPMENT

The student must be able to:

1. Make the proper selection of a search unit for three different test situations.
2. Select and properly apply couplant to a search unit.
3. Perform at least three tests using the pulse echo technique.
4. Perform a test using the through transmission technique.
5. Perform at least two tests using the immersion technique.
6. Perform at least three tests using the angle beam technique.

### BLOCK IV - INTERPRETATION OF INDICATIONS

The student must be able to:

1. Interpret at least three simulated test displays on the cathode ray tube.
2. Distinguish between an irrelevant and true indication.
3. Recognize back reflections and interpret pulse height and saturation.

BLOCK V - USE OF STANDARD REFERENCE BLOCKS

The student must be able to:

1. Perform a check on an angle beam search unit using the angle beam calibration block.
2. Perform a linearity calibration check on the ultrasonic instrument using the area, distance calibration blocks.
3. Perform a sensitivity check on the ultrasonic instrument using the resolution block.

BLOCK VI - ADVANTAGES AND LIMITATIONS OF ULTRASONIC TESTING

The student must be able to:

1. Perform an "in field" test on equipment in service.
2. List and discuss advantages and limitations or ultrasonic testing.

BLOCK VII - SAFETY AND WORK PRECAUTIONS

The student must be able to:

1. Discuss any safety and work precautions he has learned while operating ultrasonic equipment.

BLOCK VIII - QUINMESTER POST-TEST

The student must be able to:

1. Satisfactorily complete the quinmester post-test.

Course Outline

AVIATION QUALITY CONTROL - ADVANCED - 9227
(Ultrasonic Testing)

Department 48 - Course 9227.03

I. THEORY OF SOUND

A. Methods of Sound Wave Generation
   1. The piezoelectric principle
   2. The magnetostrictive principle

B. Wave Forms of Ultrasonic Sound
   1. The longitudinal wave mode
   2. The shear wave mode
   3. The surface wave mode

C. Ultrasonic Sound Wave Propagation
   1. Particle movement in the longitudinal wave mode
   2. Particle movement in the shear wave mode
   3. Particle movement in the surface wave mode
      a. Direction of travel
      b. Surface penetration

D. Ultrasonic Sound Wave Frequency
   1. Explanation of the term frequency as applied to wave form
   2. Ultrasonic sound working frequency ranges.
   3. Effect of frequency on penetration

E. Ultrasonic Sound Wavelength
   1. Define the term wavelength
   2. Formula for computing wavelength
   3. Effects of wavelength on penetration
   4. Effects of wavelength on resolution

F. Ultrasonic Sound Wave Velocity
   1. Explain the term velocity as to wavelength
   2. Effect of velocity on wave mode

G. Reflection and Refraction of Ultrasonic Sound Waves
   1. Explain the term reflection as to sound wave direction
   2. Explain the term refraction as to sound wave direction
      a. Causes of sound wave refraction
      b. The direction of the refracted sound wave in relation to the incident angle.
   3. Computing the refracted angle using Snell's Law
      a. The first critical angle
      b. The second critical angle
   4. The need for knowing these angles
      a. Wave mode change
      b. Direction of travel

H. Sound Beam Spread or Divergence
   1. Formula for computing beam spread
   2. Effect of beam spread on sensitivity and wave mode

I. Sound Beam Attenuation

J. Sound Beam Impedance
   1. Formula for computing impedance
   2. Effects of impedance on the sound wave

II. EQUIPMENT USED IN ULTRASONIC TESTING

A. The Ultrasonic Reflectoscope
   1. The function of cathode ray tube screwdrive adjustments
      a. Brightness
      b. Focus
      c. Marker position
      d. Vertical
      e. Horizontal
   2. The function of the cathode ray tube display panel controls
      a. Sweep delay
      b. Sweep
      c. Markers
   3. The function of the pulser-receiver unit panel controls
      a. Pulse length
      b. Pulse tuning
      c. Sensitivity
      d. Reject
      e. Frequency
      f. Test mode switch
      g. Transducer cord jack recepticles

B. The Transigate
   1. The function of the transigate
      a. Audible alarm
      b. Visible alarm
   2. Transigate panel controls
      a. Gate start
      b. Gate length
      c. Alarm mode switch
      d. Alarm level

C. Immersion Tank
   1. Tank sizes and capacities
   2. Automatic or manual bridges
   3. Method of display presentation

D. Search Units (Transducers)
   1. Construction:
      a. X-cut crystal
      b. Y-cut crystal
      c. Internal ground
      d. External ground
      e. Focused

II. EQUIPMENT USED IN ULTRASONIC TESTING (Contd.)

2. Crystal materials
   a. Quartz
   b. Barium titanate
   c. Lithium sulfate
   d. "Z" crystals

III. TECHNIQUES IN USING ULTRASONIC EQUIPMENT

A. Proper Selection of Search Units
   1. Size or diameter of face
   2. Material used for crystal
   3. Nonfocus or focus type
   4. Angle beam
   5. Special application units
      a. Wheel
      b. Bubbler
      c. Paint brush
      d. Needle

B. Search Unit Couplant
   1. Function of couplant
   2. Selection of couplant
   3. Using the couplant

C. Pulse Echo Technique
   1. Single search unit
   2. Double search unit

D. Through Transmission Technique

E. Immersion Technique

F. Angle Beam Technique
   1. Using the shear wave mode
   2. Using the surface wave mode

G. Setting Up the Reflectoscope
   1. Connecting search unit leads
   2. Positioning test mode switch
   3. Adjusting sweep delay controls
   4. Adjusting marker controls with standard
   5. Adjusting the pulse echo unit controls
   6. Adjusting the transigate unit controls

IV. INTERPRETATION OF INDICATIONS

A. Cathode Ray Tube Display (A-Scan)
   1. Position of the initial pulse
   2. Position of the back reflection

a. Time - distance between initial pulse and back reflection
b. Attenuation of the back reflections

3. Multiple back reflections
4. Pulse height and saturation
5. Front surface pulse in immersion testing
6. Noise or "grass" on sweep line
7. True indications of a discontinuity

B. Facsimile Recorder (C-Scan)
1. Plan view presentation
2. Plus or minus mode

V. USE OF STANDARD REFERENCE BLOCKS

A. Angle Beam Calibration Block
1. Determining point of incidence of angle beam search units
2. Determining refraction angle of angle beam search units
3. Determining travel distance with angle beam search units

B. Area Amplitude Calibration Blocks
1. Determining size of discontinuity by comparison
2. Calibrating the reflectoscope

C. Distance Amplitude Calibration Blocks
1. Determining depth of discontinuity by comparison
2. Calibrating the reflectoscope

VI. ADVANTAGES AND LIMITATIONS OF ULTRASONIC TESTING

A. Depth Penetration of Sound Waves

B. Near Surface Resolution

C. Portability of Equipment

D. Ability To Work from One Surface

E. Type of Presentation
1. Instant indications
2. Lack of permanent record

VII. SAFETY AND WORK PRECAUTIONS

A. Danger, If Any, To Operating Personnel

B. Complexity of Instruments and Delicate Crystals

VIII. QUINMESTER POST-TEST

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10. Weeks, William R. Metallurgy. 4th ed. Chicago: American Technical Society, 1957. n.p.


Films:

1. Drama of Metal Forming, The. 16 mm. 28 min. Color. Sound. Shell Oil Co. Film Library.

2. Modern Steel Making. 16 mm. 32 min. Color. Sound. Associate Sterling Films.

3. Quality Assistance. 16 mm. 19 min. Color. Sound. George T. Baker Aviation School.

# APPENDIX

Quinmester Post-Test Sample

Quinmester Post Test

Name _____ Date _____ Score ___

Multiple Choice Test Items

Each statement needs a word, a figure, or a phrase to make it correct. Only one of the choices listed is correct. Mark the letter of the choice you make between the dotted lines adjacent to the number of the question on the answer sheet.

1. The particle motion in longitudinal waves is:

   a. Parallel to the direction of wave propagation
   b. Intermittent
   c. Elliptical
   d. Perpendicular to the direction of wave propagation

2. Two other types of sound wave propagation are:

   a. Surface and standing waves
   b. Standing and oscillating waves
   c. Surface and shear waves
   d. Standing and shear waves

3. Ultrasonic test frequencies, most commonly used for inspection of materials covered in this course, are in the range of:

   a. 20 to 150 kHz (kilohertz)
   b. 0.2 to 25 MHz (megahertz)
   c. 10 to 250 MHz
   d. 1 to 15 kHz

4. Ultrasonic waves transmitted in water and other liquids are usually:

   a. Shear waves
   b. Lamb waves
   c. Longitudinal waves
   d. Rayleigh waves

5. Liquid couplants are used to:

   a. Insulate the transducers from the test parts
   b. Absorb sound energy
   c. Transmit sound energy
   d. Reflect sound energy

6. The acoustic impedance of a material to ultrasound is equal to:

   a. The product of material density and wave velocity
   b. The ratio of material density to wave velocity
   c. The ratio of sound velocity to wave length
   d. None of the above

7. The velocity of shear waves in most materials as compared to longitudinal wave velocity is:

   a. Two times faster
   b. One half as fast
   c. Three times faster
   d. The same

8. Surface (Rayleigh) waves penetrate material:

   a. At an obtuse angle
   b. About three and one-half wave lengths
   c. Less than one-half wave length
   d. Approximately one wave length

9. Snell's Law relates the angle of the incident sound beam to:

   a. The direction to incident beam propagation
   b. The angle of the refracted beam
   c. The coefficient of scattering
   d. The angle of the surface reflection

10. The refracted angle of a sound beam passing from water into a metal part, at an angle to the interface, is a function of:

   a. The frequency of the sound beam
   b. The acoustic impedance ratio of water to metal
   c. The relative velocities of sound in water and metal
   d. The surface finish of the part

11. As the test frequency increases, the angles of beam divergence of a given diameter transducer:

   a. Decreases
   b. Remains unchanged
   c. Increases
   d. Varies exponentially in relation to the wave length

12. Increased surface roughness affects test results by:

   a. Improving resolutions
   b. Decreasing sensitivity
   c. Improving sensitivity
   d. Decreasing scattering

13. Maximum longitudinal wave energy enters the part when the sound beam:

   a. Is normal to the part at the entry surface
   b. Is at the critical angle for longitudinal waves
   c. Is beyond the critical angle for longitudinal waves
   d. Is reflected according to the inverse square law

14. Test blocks are used:

a. As a reference to determine estimated defect size
b. To measure material thickness
c. To compensate for attenuation variables
d. To change the propagation mode

15. The piezoelectric material in a search unit which vibrates to produce ultrasonic waves is called:

a. A backing material
b. A lucite wedge
c. A crystal
d. A couplant

16. A test method employing two separate search units on opposite surfaces of the material being tested is called:

a. Contact testing
b. Surface wave testing
c. Through transmission testing
d. Lamb wave testing

17. The indication of the oscilloscope screen which represents the far boundary of the material being tested is called:

a. Hash
b. The initial pulse
c. The "main bang"
d. The back reflection

18. An ultrasonic testing technique in which the crystal is at an angle to the test surface is called:

a. Angle beam testing
b. Immersion testing
c. Contact testing
d. Through transmission testing

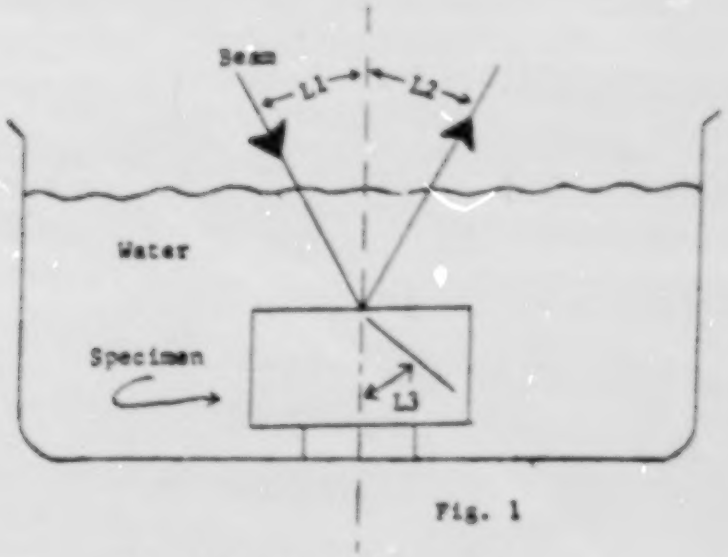


Fig. 1

19. In Figure #1, angle L1 is called the:

    a. Angle of incidence
    b. Angle of reflection
    c. Angle of refraction
    d. None of the above

20. In Figure #1, angle L3 is called the:

    a. Angle of incidence
    b. Angle of reflection
    c. Angle of refraction
    d. None of the above

21. The moving of a search unit along a test surface either manually or automatically is referred to as:

    a. Scanning
    b. Attenuating
    c. Angulating
    d. Resonating

22. A term used in ultrasonics to express the speed at which sound waves pass through various substance is:

    a. Frequency
    b. Velocity
    c. Wave length
    d. None of the above

23. When a vertical indication has reached the maximum signal height which can be displayed or viewed on the oscilloscope screen of an ultrasonic instrument, this is called:

a. Distance, amplitude, height
b. Absorption
c. Saturation
d. Attenuation

24. A term used to describe numerous small indications on the cathode ray tube screen, resulting from test part structure, numerous small discontinuities or both, is referred to as:

a. Multiple back reflections
b. Multiple front reflections
c. Hash
d. Resonance

25. In immersion testing, proof that the search unit is normal to a flat entry surface is indicated by:

a. Maximum reflection from the entry surface
b. Elimination of water multiples
c. Proper wave length
d. Maximum amplitude of the initial pulse

26. Sound waves of a frequency beyond the hearing range of the human ear are referred to as ultrasonic waves or vibrations, and the term embraces all vibrational waves of a frequency greater than approximately:

a. 20,000 Hz
b. 2 MHz
c. 2 kHz
d. 200 kHz

27. Which of the following search units would contain the thinnest quartz crystal:

a. 1 MHz
b. 5 MHz
c. 15 MHz
d. 25 MHz

28. When inspecting coarse grained material, which of the frequencies below will generate a sound wave that will be most easily scattered by the grain structure:

a. 1.0 MHz
b. 2.25 MHz
c. 5 MHz
d. 10 MHz

29. Which of the following search units would contain the thickest quartz crystal:

a. 1 MHz
b. 5 MHz
c. 15 MHz
d. 25 MHz

30. Under most circumstances, which of the following frequencies would result in the best resolving power:

a. 1 MHz
b. 5 MHz
c. 10 MHz
d. 25 MHz

31. When testing by the surface wave method, patches of oil or dirt on the surface will:

a. Block the progress of all sound
b. Attenuate the sound but cause no indications on the screen
c. Have no effect on the test
d. Cause both an attenuation of sound and indications on the screen

32. In immersion testing, the most commonly used couplant is:

a. Water
b. Oil
c. Glycerine
d. Alcohol

33. The piezoelectric material in the search unit:

a. Converts electrical energy to mechanical energy
b. Converts mechanical energy to electrical energy
c. Both No. 1 and 2
d. Neither No. 1 nor 2

34. The gradual loss of sonic energy as the ultrasonic vibrations travel through the material, is referred to as:

a. Reflection
b. Refraction
c. Reproducibility
d. Attenuation

35. A general term applied to all cracks, inclusions, blowholes, etc., which cause a reflection of sonic energy is:

a. Disperser
b. Discontinuity
c. Attenuator
d. Refractor

ANSWER KEY FOR QUINMESTER POST-TEST

1. a
2. c
3. b
4. c
5. c
6. a
7. b
8. d
9. b
10. c
11. a
12. b
13. a
14. a
15. c
16. c
17. c
18. a
19. a
20. c
21. a
22. b
23. c
24. c
25. d
26. a
27. d
28. d
29. a
30. d
31. d
32. a
33. c
34. d
35. b